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Vessel Traffic Services (VTS) : the management and monitoring of maritime traffic in light of the new technology of the Automatic Identification System (AIS)

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VESSEL TRAFFIC SERVICES (VTS): THE MANAGEMENT AND MONITORING OF MARITIME TRAFFIC IN LIGHT OF THE NEW TECHNOLOGY OF THE AUTOMATIC IDENTIFICATION SYSTEM (AIS)

By

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DECLERATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal view, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Vessel Traffic Services (VTS): The management and monitoring of maritime traffic in light of the new technology of the Automatic Identification System (AIS)**

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This dissertation is a study of the impact of introducing the new technology of the Automatic Identification System (AIS) in the Vessel Traffic Services (VTS) by assessing the benefits and limitations of integrating AIS as an additional sensor for VTS.

A general overview of the VTS principles of operations, according to IMO and IALA recommendations, will be provided to the reader. Furthermore, the study will discuss the development and present methods of operating vessel traffic services, including the training and qualification of VTS personnel.

A brief look will be taken at the operational principles of AIS, including the self-organizing time division multiple access (SOTDMA) technology, which allows the system to broadcast information at a high rate, as well as the performance and presentation standards.

Applying AIS technology will improve many of the VTS functions. The areas of VTS operations, which will be affected and influenced by applying AIS technology, will be identified. Furthermore, the result of introducing information technology in improving VTS operations, which is related to the safety, management and monitoring of maritime traffic will be clarified.

Additionally, some of the limitations associated with the use of AIS technology for VTS will be examined. Finally, the conclusions will summarize the findings of this study, and a number of recommendations will be proposed for the organization concerned with the development of AIS technology.

KEYWORDS: VTS, AIS, Monitoring, Management, Safety of Navigation, Information Technology, Identification, Communication, Detection, Tracking, Integration, Training.

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LIST OF ABBREVIATIONS

ADSS	Automatic Dependent Surveillance System
AIS	Automatic Identification System
ALRS	Admiralty List of Radio Signals
ARPA	Automatic Radar Plotting Aid
BAFEGIS	Baltic Ferry Guidance and Information System
BIIT	Built-in Integrity Test
COG	Course Over Ground
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
COMSAR	Sub-Committee on Radio communications and Search and Rescue
COSPAS-SARSAT	International Satellite System for Search and Rescue
CPA	Closest Point of Approach
DAC	Designated Area Code
DGPS	Differential Global Positioning System
DSC	Digital Selective Calling
ECDIS	Electronic Chart Display and Information System
EMPA	European Maritime Pilot Association
ENRI	Electronic Navigation Research Institute
EPIRB	Emergency Position Indicating Radio Beacon
ETA	Estimated Time of Arrival
EU	European Union
FI	Function Identifier

GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
GNSS	Global Navigation Satellite system
IAI	International Application Identifier
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technology
IEC	International Electrotechnical Committee
IFM	International Function Messages
IFSMA	International Federation of Shipmasters' Associations
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IMPA	International Maritime Pilot association
IMRAMN	International Meeting on Radio Aids to Maritime Navigation
INMARSAT	International Mobile Satellite Organization
ITU	International Telecommunications Union
MET	Maritime Education and Training
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity Number
MSC	Maritime Safety Committee
MSI	Maritime safety Information
NAV	Sub-Committee on Safety of Navigation
NM	Nautical Mile
PPU	Portable Pilot Unit

POSEIDON	European Project on Integrated VTS, Sea Environment and Interactive Data On-Line Network
PC	Personal Computer
PTMS	Port Traffic Management System
RACON	Radar Transponder Beacon
RADAR	Radio Directing and Ranging
RAI	Regional Application Identifier
RCC	Rescue Coordination Center
RO\RO	Roll on Roll off
ROT	Rate of Turn
SAR	Search and Rescue
SART	Search and Rescue transponder
SOG	Speed Over Ground
SOLAS	International Convention for the Safety of Life at Sea
SOTDMA	Self Organizing Time Division Multiple Access
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STCW Code	Seafarers' Training, Certification and Watchkeeping Code
TCPA	Time to Closest Point of Approach
UK	United Kingdom
US	United States of America
USA	United States of America
USCG	United States Coast Guard
UTC	Coordinated Universal Time
VHF	Very High Frequency

VTMIS	Vessel Traffic Management and Information System
VTMIS NET	Vessel Traffic Management and Information System Network
VTS	Vessel Traffic Services
WMU	World Maritime University

Chapter 1

Introduction

The importance of shipping is represented in the amount of trade carried by sea. Shipping throughout history has always been the most convenient means of moving people and cargo. So as to sail safely across the seas and oceans, the navigators always needed navigational assistance.

The need for navigational assistance resulted in the development of various aids to navigation systems. These aids to navigation systems have proven to be of limited efficiency, as their efficiency was conditioned and constrained by various factors including:

- Range of visibility,
- Disability to interact with maritime traffic,
- Meteorological and hydrographical conditions,
- Malfunctions and difficult operating and maintenance conditions,
- Difficulty in controlling from shore.

What the mariners really required was a system that had the capability of interacting with the traffic, as well as responding to traffic situations developing in its area of service. The invention of radio directing and ranging (RADAR), followed by the invention of further sophisticated systems in tracking and monitoring maritime traffic, including automatic radar plotting aid (ARPA) and electronic chart display and information systems (ECDIS). The invention of these systems made it possible to establish an efficient shore based vessel traffic services systems (VTS).

Although, radar surveillance systems were established as early as 1948, neither these systems nor other aids to navigation systems had the capability to interact and respond to traffic situations. The VTS systems were developed as a live solution for traffic management and surveillance problems, by interacting with ships, advising and assisting them to ensure the safety and efficiency of navigation.

The International Maritime Organization (IMO) has acknowledged the contribution of VTS to safety of life at sea, safety and efficiency of navigation and the protection of the marine environment, adjacent shore areas, work sites and offshore installation from possible adverse effects of maritime traffic (SOLAS, 2001). Furthermore, IMO and the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) have published many guidelines and recommendations to assist VTS in improving their technical and professional performance.

IMO adopted a new requirement for ships to carry automatic identification system (AIS), which is capable of providing information - including the ship's identity, type, position, course, speed, navigational status and other safety and navigation related information - about the ship to other ships and to coastal authorities. AIS was introduced to improve the safety and efficiency of navigation and the protection of the environment.

The standard performance of the AIS consists of functionality performance standards, which were set by IMO and IALA. While the International Telecommunications Union (ITU) set the technical specifications and the International Electrotechnical Committee (IEC) adopted the type approval standards.

AIS will be a great tool for VTS operations in generating a comprehensive view of the traffic in the VTS area. It will help the VTS in compiling the traffic image of the VTS area. This may include fairway situations, traffic situations as well as data of vessels in accordance to the requirements of ship reporting system. AIS will facilitate significantly the tracking of traffic as well as the communication process throughout the VTS area.

Furthermore, AIS will improve the quality of shipping information services, which will support the trend of converting VTS to vessel traffic management and information systems (VTMIS) by providing wider comprehensive traffic information. Moreover, AIS will contribute positively to many of the VTS applications and allied services, which contribute to ensure the safety and efficiency of navigation as well as the monitoring and management of maritime traffic.

1.1 Objectives

The objectives of this dissertation are:

- To identify the role of VTS in managing and monitoring of maritime traffic in order to ensure safety and efficiency of navigation,
- To identify the principles of AIS,
- To evaluate the impact of introducing AIS technology in VTS operations,
- To discuss the advantages of integrating other navigational systems to AIS to facilitate the management and monitoring of the maritime traffic by VTS,
- To examine the limitation associated with the use of AIS in VTS,
- To make proposals and recommendations to improve the function of the VTS by introducing the AIS.

1.2 Questions Raised

In carrying out this dissertation a number of questions will be posed to which answers will be sought.

1. How is the VTS used to ensure the safety and efficiency of navigation?
2. What are the operational principles of AIS?
3. How would AIS improve VTS operations in relation to safety, efficiency and security of maritime traffic?

4. What is the impact on VTS efficiency when AIS is integrated with the other existing VTS tools in operation?
5. What are the limitations of AIS as an additional VTS tool?

1.3 Methodology

This dissertation includes a literature search of the current operational principles and methods of operating VTS and AIS. Due to the subject matter being a new technology, few textbooks were published incorporating issues about AIS technology. Therefore, much of the research was done primary on research papers, performance standards and mandatory requirements specified by law making bodies, such as IMO, as well as technical specifications and guidance given by other organizations, such as IALA, IEC and ITU.

The author has been in contact, by e-mail or during World Maritime University (WMU) filed studies, with a number of organizations, which are concerned with the design as well as the operations of VTS. Those organizations, including electronic navigation research institute (ENRI) in Japan, Horton traffic VTS in Norway, office of the traffic management in the US Coastguard, (IALA-AISM), Atlas Elektronik GMBH in Germany, Tokyo Wan traffic advisory service center in Japan and Kongsberg maritime ship system in Norway and others. Moreover, online references have been included.

1.4 Summary of Chapters

The remainder of this dissertation is divided into the following chapters:

- Chapter 2 provides a general overview of the role of VTS in managing and monitoring maritime traffic.
- Chapter 3 identifies the operational principles of (AIS), and compares it with the radar principle, with special regard to functionality.
- Chapter 4 examines the impact of introducing AIS in VTS operations and reveals the different application, which the AIS can contribute to.

- Chapter 5 discusses the limitations associated with the use of AIS in VTS operations.
- Chapter 6 draws the final conclusions on the topic research within this dissertation.

1.5 Limitations

The author acknowledges that there were limitations in length and time. He emphasizes that the issue is still to be discussed and analyzed. Therefore the author strongly advices that further research should be undertaken in this issue.

Chapter 2

The Role of Vessel Traffic Services in Managing and Monitoring Maritime Traffic

2.1 Developments of VTS

According to IMO Resolution A.857 (20) VTS is defined as:

> A VTS is a service implemented by a competent authority, designed to improve safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area. (3)

VTS is not a new concept. Different methods have been used in the past to manage maritime traffic, in particular port approaches. Methods such as flares and smoke signals were lit from the shore to the approaching ships; a sophisticated system of semaphore and flags were developed later to assist in ship-shore communications. It was common for ships to anchor outside the ports. Due to bad weather or restricted visibility, it was not possible for ports to determine exactly, what time ships were arriving.

Robert Watson of Bratin invented the radio before the end of the 19th century followed by the invention of radar in 1935. Radar systems were placed along the south coast of the United Kingdom by 1938. During the Second World War the radar systems were used to detect aircraft, at any time and in any weather conditions.

The radar has proved its effectiveness in monitoring and tracking different targets including maritime traffic. In 1946 the International Meeting on Radio Aids to Maritime Navigation (IMRAMN) pointed out the value of radar for shore surveillance purposes and studied the possible need for shore-based radar as an aid to marine navigation.

The first radar surveillance system was established in Liverpool in 1948; another radar surveillance system was established in Long Beach, California in the USA in 1950, followed by a system of radar stations for the surveillance of traffic, established by the Netherlands at the port of Rotterdam.

Further developments were required to improve the management and monitoring of maritime traffic in order to ensure the safety of navigation; numerous applications were used, such as:

- Traffic Separation Schemes (TSS).
- Recommended routes and routing measures.
- Precautionary zones, directions and speed limit in certain areas.
- Inshore traffic zones.
- Additional requirements for ships carrying dangerous cargoes.
- Radio aids to navigation including Navigation warnings and Weather forecast.

None of the above mentioned techniques had the capability of either interacting with the traffic or providing any advice or assistance to the vessels, therefore the VTS was developed as a live solution for traffic management and surveillance problems, by interacting with the vessels, to advice and assisting them to ensure the safety and efficiency of navigation.

At the moment VTS technology uses very sophisticated Video-Audio systems, auto tracking systems, as well as, automatic identification systems and other modern systems in order to cope with the increase in maritime traffic. Thus the new technology used in building and operating ships is a result of the massive development of the international trade.

As a result of the significant increase of the maritime traffic density in Japan in the late 1960's, ENRI have conducted four major surveys with reports published in 1978, 1984, 1989 and 1997. Based on the author's personal contacts with many of the organizations concerned with VTS operations, literature search as well as searching the Internet sources; apparently, this is the only published statistics with regard to this subject.

According to ENRI, the number of VTSs (Nv) and VTS radars (Nr) has increased rapidly around the world, as it is shown in figure 2.1.

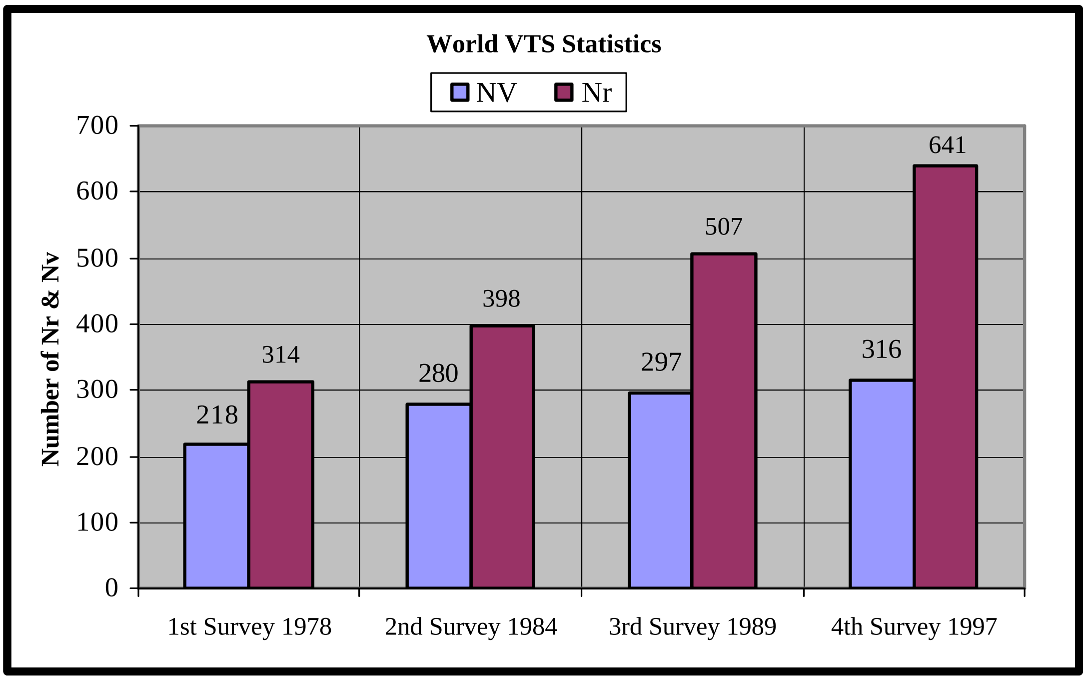

Figure 2.1 - Number of VTS (Nv) & surveillance radar (Nr)
Source: Electronic Navigation Research Institute. (1997). Paper 89. Japan: Author

The Nv and Nr are distributed geographically around the globe; more centers were established in areas with high traffic density in the developed countries, which control most of the world maritime trade.

Figure 2.2 illustrates the distribution of world VTS & Surveillance radars number in 1997, According to the ENRI.

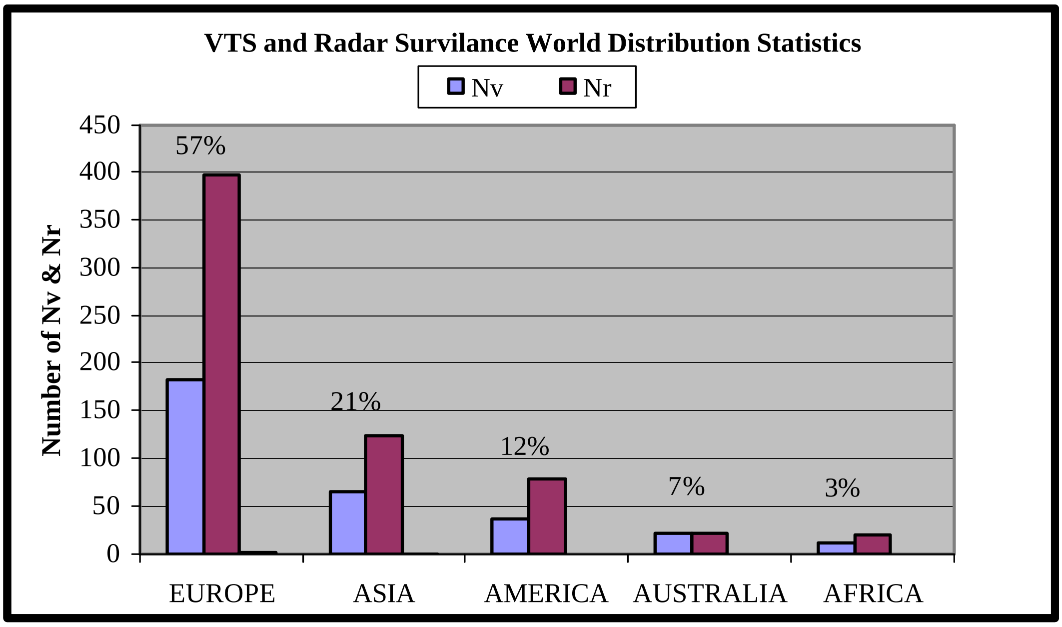

Figure 2.2 - The distribution of world VTS & Surveillance radars
Source: Electronic Navigation Research Institute. (1997). Paper 89. Japan: Author

2.2 The Purpose of VTS

Initially VTS was established to ensure safety of navigation; the scope of utilization of the VTS was broadened later to include commercial and other purposes. From the safety point of view, according to IMO the VTS will improve the following:

- The safety of navigation,
- The safety of life at sea,
- The efficiency of navigation,
- The protection of the environment,
- The identification and monitoring of vessels,

- The planning of vessel movement and provision of navigational information and assistance.

From the commercial point of view, VTS can assist port operations with regards to resource management and time organization, avoid traffic delay, and increase the efficiency of the traffic flow.

The VTS can be a great tool in other maritime operations, such as naval activities, maritime security, oil and gas production, tourism activity and several other activities.

2.3 Type of VTS

Basically there are two main types of VTS; a VTS center functions as port or harbour VTS, coastal VTS or both of them simultaneously. A VTS area can be subdivided into sub-areas or sectors. Boundaries of the subdivide areas or sectors should not be located where vessels are normally altering course, manoeuvring, crossing traffic, approaching route junctions and convergence areas.

2.3.1 Port or Harbour VTS

The Port or Harbour VTS is mainly concerned with the traffic of vessels to and from the port or ports in a certain area, including traffic organization, navigational assistance, pilot embarking/disembarking and berthing.

Ports are of different nature and layouts; some ports are located in rivers or inland waters far away from the sea e.g. Rio de La Plata in Argentina and New Orleans in the USA, other ports are located just on the coast protected by break waters from the sea e.g. Port of Kaohsiung in Taiwan and Alexandria in Egypt, other ports as well are located at high traffic density areas or areas with navigational difficulties, such as many small islands, fishing activities, tourism activities, offshore platforms and others e.g. Hong Kong, Singapore and the south approach to Suez in Egypt.

2.3.2 Coastal VTS

The Coastal VTS is mainly concerned with maritime traffic passing through certain areas, for the purpose of safety of navigation, traffic flow, national security, search and rescue (SAR), fishing surveillance, environmental purposes and other safety and economical purposes. It provides information service, as well as, monitoring and identification of ships. Examples of coastal VTS:

- The channel navigation information service in Dover.
- The Singapore Vessel Traffic Information Center.
- The Malaysia Vessel Traffic Information Center.

2.4 Services Provided by VTS

The type of services provided by the VTS will depend on many factors including:

- The geographical area covered by the VTS,
- The local hydrological and metrological condition of the area,
- The density and type of traffic normally utilizing the VTS area,
- The pattern of traffic including type of ships, size of ships and cargo carried,
- The capabilities of the organization involved in providing such services in co-operation with the VTS, e.g. Port Authorities, weather forecasting centers, pilot station and pollution control centers.

Depending on the above factors and others, VTS basically provide 4 types of services, namely information services, navigational assistance, traffic organization services and co-operation with allied services and adjacent VTS.

2.4.1 Information Services

Information related to the safety of navigation and the facilitation of the traffic flow is provided at fixed intervals, at the request of a certain ship or when the VTS management considers it necessary; the information is broadcast to assist ship's masters in making essential decisions.

Such information may include, position reports, identification of other vessels or objects, weather and sea conditions, navigational hazards and any other information or factors which may affect the safe transit of the traffic.

2.4.2 Navigational Assistances Services

It may be necessary to provide navigational assistance in several situations, for example in the case of a defect occurring to a certain ship or its equipment or in situations of navigational difficulties due to metrological and hydrological conditions.

Navigational assistance is provided on request of the ship or when the VTS operator considers it necessary, and only if the VTS operator is able to establish affirmative identification of the vessel throughout the whole process.

The service provided is to assist the master of the vessel in decision making, such as course and speed made good by the vessel, position relative to an object or way point or any assistance required to ensure the safe transit of the traffic and the safety of navigation.

2.4.3 Traffic Organization Services

Traffic organization services are interpreted as the planning of the traffic movements by introducing regulations, which the users of the VTS have to comply with and adhere to, for the best safe and efficient movement of the traffic within the VTS area.

These services are provided to prevent congestion and dangerous situations in all traffic situations. Establishing and operating a specific system or systems in order to perform these services may be necessary. Such systems may be in a form of traffic clearance requirement, VTS sailing plan, designating speed limit zones and others.

The instruction given by the VTS to any vessel must be of a result-oriented nature and the ship's masters are responsible for the details of implementation.

2.4.4 Co-operation with Allied services and Adjacent VTS

Many of the different stakeholders of the maritime industry are interested in the VTS traffic information or at least some parts of it. However different parties are interested in different kinds of information, e.g. a pilot station will be interested mostly in ship's estimated time of arrival (ETA) among other information. The VTS is now considered to be a valuable information source to the whole maritime community.

Gathering and processing of such information requires the VTS to identify the bodies and organization concerned, to establish line of communications and information exchange. Allied services may include, pilot stations, search and rescue centers, port operations, coast guard, port state control and other VTS centers.

2.5 VTS Technical Operations

The operation procedures of a VTS are of two different categories:

- Daily routine procedures,
- Contingency procedures.

Under each category of operation procedure, there are two types of operations, the internal operations, which are concerned with the internal organization of the VTS center and the external operations, which deal with the interactions with the users of the services and the allied services co-operating with the VTS.

In order to ensure the effectiveness of the operations, three main inputs have to be appropriately analysed and qualified:

- The traffic image,
- The human resources (the VTS personnel),

- The VTS procedures and methods of operations.

2.5.1 The Traffic Image

In order to provide the VTS services, the VTS operator require to be provided with a traffic image, which is a continuous updated image gathered from different sources including all the participants of traffic in the VTS area, and a technique to assist the operator in evaluating the situations.

The technology used in providing the traffic image may vary from an old style analogue radar display to the use of modern sophisticated ECDIS associated with radar and AIS information. The data required to obtain the traffic image are mainly categorised as:

- The fairway situation: information including the metrological and hydrological conditions and the operational conditions of the aids to navigation.
- The traffic situation: information including the movements of vessels, cargo carried and the state of ship's hull and machinery conditions.
- Information necessary in complying with the ship reporting requirements and any other additional information required for the effective operations of VTS.

The use of modern sophisticated technology in obtaining the VTS traffic image will result in more accurate, reliable and credible image; such image will assist the VTS operator in assessing the traffic situations. Moreover, it will enhance and facilitate the decision making process.

A comprehensive overview of the traffic image must be available to the VTS operator at all times, taking into account all the factors which may affect the movement of the traffic and enabling the VTS operator to obtain full information about each vessel and its intentions.

The decisions and results of the traffic image evaluation should be communicated to the transiting traffic in the VTS area. Different types of message are broadcast, such as periodical messages of navigational information and other information. Critical navigational information must be transmitted as soon as it is available and other communications with particular ships interacting with the VTS. Normally the VHF is the equipment used for such communications. The use of AIS will improve the effectiveness of the communications significantly.

Initially the visual observations were the only methods of target tracking. The introduction of radar followed by radar/ARPA introduced an auto tracking of targets; the use of AIS will provide a second method of auto tracking, when integrated with the previously used systems (Radar; ARPA; ECDIS) will result in a more reliable and valid traffic image.

2.5.2 VTS Personnel

The increasing number of VTS systems around the world, which provide a range of services to the users, and the use of modern sophisticated equipment in operating such systems established the need for properly qualified and trained VTS personnel. According to IMO investigations the VTS personnel entry requirements in different states varies from non-nautical background personnel to masters and pilots.

The IMO has considered the importance of developing training and certification provisions in resolution 10 of the STCW 1995 conference. The IMO Assembly resolution A.857 (20) annex 2 " guidelines on recruitment, qualification and training of VTS operators" describes the skills and knowledge required for the VTS personnel in performing their required tasks, as well as assisting the authorities in developing such standards to enable the VTS personnel to carryout their functions properly.

IALA had published many guidelines and recommendations regarding the standard of training and qualification of VTS operators including:

- IALA recommendation V-103 (1998) on standard for training and certification of VTS personnel, which provide the authorities with the methods of training, qualifications, certification and evaluating of the VTS personnel. Moreover, it demonstrates the standard of competency using competency charts similar to the competency tables of the Seafarers' Training, Certification and Watchkeeping (STCW) Code. It also provide the basis of model courses, such as:
  - Model course V-103/1 – Vessel Traffic Services operator basic training.
  - Model course V-103/2 – Vessel Traffic Services supervisor – Advancement Training.
  - Model course V-103/3 – Vessel Traffic Services on the Job Training.
  - Model course V-103/4 – Vessel Traffic Services on the Job Instructor.
- Guidelines for the accreditation of the VTS training institutes (2001), specifies the structure of training and assessment, the qualified instructors, as well as, the relevancy and accuracy of the training.
- IALA guidelines on the assessment of training requirements for existing VTS personnel, candidate VTS operators and revalidation of VTS operator's certificates (2001).
- IALA guidelines on designing and implementing simulator in VTS training at training institute and VTS centers.

The above-mentioned recommendations, guidelines and others are published to improve the technical and professional capabilities of the VTS operators in order to meet the objectives and purpose of VTS. IMO has recognised IALA model courses and invited member states to adopt them in preparing their VTS operators.

2.5.3 VTS Procedures and Methods of Operations

A common vessel traffic service scenario commences when a vessel approaches a reporting point located at one end of the VTS area. The vessel reports her intended sailing plan through the VTS area, among other reported items. The VTS operator monitors the vessel during her transiting to ensure adherence, as well as providing VTS services. If the vessel is calling a port located in the VTS area, the VTS operator monitor and guide the vessel to the pilot station.

Vessels may require communicating with the VTS center for information updating, including deviation from initial sailing plan or for the report of failure. The final stage for the service takes place when the vessel comes to the end of the VTS area or when alongside the quay. In many VTS centers, this may require to report "all clear" to the VTS center when clear.

IALA - VTS manual. (2002), specifies three principle methods to organize traffic, which can be used independently or integrated together. These three methods are:

- Geographical division: it is a passive traffic management technique, which separates traffic streams by instituting Traffic Separation Schemes, designating anchorage areas for all, or special categories of ships, designating areas for cross traffic or others.
- Time separation: it is achieved by a vessel having exclusive use of a certain area or a restricted passage for a given time span.
- Distance separation: it is a method whereby vessels are given a minimum distance between each other in order to transit the whole or certain areas and restricted passages.

In order to perform the VTS operations, VTS centers are obliged to set rules and regulations to be followed in the VTS area, including operation procedures for monitoring and managing the traffic in the VTS area. Among the most crucial procedures are:

- Data collection: to enable VTS to establish comprehensive traffic image as well as VTS database; such as the collection of traffic and fairway situations from VTS allied services and other VTS centers using different communication methods, as well as vessels in the VTS area by means of communication or by monitoring them, using VTS tools including radar, ECDIS, AIS and television screens.

- Data Evaluating: evaluating the collected data is the second vital procedure, mainly to judge the VTS intervention with the passing vessels, with regard to the rules and regulation to be adhered to in the VTS area and the movement of other vessels in the VTS area, as well as the layout of the VTS area including:
  - Shallow areas,
  - Navigational hazards,
  - Restricted areas for navigation,
  - Traffic separation schemes,
  - Metrological and hydrographical conditions,
  - Recommended and mandatory routes.

  Certainly, the layout of the traffic area as well as the traffic density in the VTS area are the most fundamental factors governing the level of sophistication and technology required in the VTS equipment, including the need for computer software to assist the VTS operator in evaluating traffic and manage other VTS services, particularly in critical situations, and to warn the VTS operator of dangers, such as the attempt to breach the VTS traffic rules by some vessels.

- Dissemination of Information: it is the ability of the VTS center to communicate the decisions resulting from the assessment of the traffic situation and other information to the vessels in the VTS area.

2.6 Further Developments of VTS

Further developments of VTS were introduced to utilize the system facilities in additional tasks, in addition to safety of navigation, efficiency of traffic flow and the protection of the environment.

Applications were introduced to add value to the VTS by providing available information to different parties interested in the maritime activities, e.g. port authorities and coast guard organizations. Involving the VTS with tasks, including economical related transport management and maritime security issues resulted in adopting new concepts, such as VTMIS.

The VTMIS concept was first started in Europe by the European Union (EU) about twenty years ago through the adoption of many projects, including Comfortable, Poseidon, VTMIS-NET and others, in order to develop and integrate the VTS, promote the water transport and improve the European industry.

According to the EU, the VTMIS is defined as a service that "intend to respond to public and private demand for facilitation vessel traffic management" with the following objectives (Hadley, 1998,p1):

- To respond to public and private demand,
- To minimise risks for safety and environment,
- To maximise efficiency of waterborne and connected transport with interlinking and co-operation of relevant services.

The exchange of information between different parties involved, e.g. VTS, pilot stations, coast guard, port authorities by developing database with the use of the new technology of information and communications (ICT), will improve the traffic management and will support the logistics operations of the transport management. Moreover, it will reduce the reporting procedures.

Another VTS application is the remote pilotage, which is rising up to the surface as remedy to the shortage of seafarers in certain regions of the world and the future potential shortage of maritime pilots among other reasons.

According to (Hadley & Pourzanjani 2003, p.184), the International Maritime Pilot Association (IMPA) and the European Maritime Pilot Association (EMPA) defines the shore-based pilotage as "an act of pilotage carried out in a designated area by a pilot licensed from that area from a position other than onboard the vessel concerned, to conduct the safe navigation of that ship."

Hadley & Pourzanjani (2003) made some assumptions in considering the use of remote pilotage taking into account its limitations, including:

- It shall be provided to certain vessel at high level of safety to the satisfaction of the authorities,
- It shall be restricted to certain type and size of ships,
- It shall not to be applied to a vessel visiting the port for the first time,
- It may require docking pilot at some stage.

VTS centers which are equipped and operated with modern technology, as well as, ships equipped with modern systems e.g. ECDIS, AIS, ARPA and global positing system (GPS) make it technically possible to adopt the shore based pilotage, bearing in mind the human factors, which will require to be developed, with respect to the ship's bridge team, including factors, such as level of training, skills, fatigue and communications.

A number of ports are using shore-based pilotage in certain situations under specific conditions for some ships. "MAAS" Pilot in the Netherlands renders shore-based pilotage, when pilots cannot embark at sea with restrictions to some ships including:

- Large vessels with a draft over 14.3 metres,
- Vessels carrying dangerous cargoes in bulk of the IMO classification 2, 3 or 6 and vessels not gas-free of the above mentioned cargo,
- Tanker ships with length exceeding 125 meters,
- Vessels with obligation (by harbour master) to have a pilot on board,
- Vessels without adequate communications possibilities,
- Vessels from which it may be expected that shore-based pilotage cannot or could not reasonably be performed safely,
- Vessels departing to sea with a length exceeding 125 meters and/or draft exceeding 9 meters.

Chapter 3

The Automatic Identification System (AIS)

3.1 The Development of AIS

Identification of floating objects by electronic aids was always deemed to be extremely essential to improve the safety and efficiency of navigation. Ever since the invention of marine radar, which enabled detection of objects, scientists and organizations involved in the maritime safety had been working in developing more advanced systems to enable the identification of objects in addition to detection.

The radar transponder beacon (Racon) was a further step ahead in identifying objects. Racon when attached to an aid to navigation or any floating object, can identify itself by sending a morse coded signal which will be displayed on the radar screen, whenever it is hit by the radar transmitted signal.

The introduction of the global maritime distress and safety system (GMDSS) in the last decade introduced the search and rescue transponder (SART), which is used in distress to detect and identify the position of a survival craft, using almost the same technique used by the racon. The emergency position indicating radio beacon (EPIRB) is another position indicating beacon using the radio frequencies to transmit identification and position of a vessel in distress via VHF or satellites such as International Mobile Satellite Organization (INMARSAT) EPIRB and EBIRB 406, which uses International Satellite System for Search and Rescue (Cospas-Sarsat) satellites.

The digital selective calling (DSC) is another technique introduced by the GMDSS. DSC allows ships and shore stations to identify other ships when receiving their maritime mobile service identity number (MMSI). According to the GMDSS, the DSC is used for communications and in distress. The United States Coast Guard (USCG) implemented an automatic dependent surveillance system (ADSS) to identify ship's in the Prince William Sound using DSC technology following the grounding of the oil tanker *Exxon Valdez* which resulted in the worst environmental damage in the US waters from ships.

While the DSC technique is based on the point to point and group communication, a new invention was initially designed for the aviation in Sweden using the self organizing time division multiple access (SOTDMA) technique, which allows stations to broadcast identification and position reports at regular and short intervals with faster speed than the DSC, allowing more ships to participate at short transmission intervals.

3.2 The implementation of the AIS

The AIS was introduced to the maritime industry through the SOLAS Convention Chapter V/19 after a long legal and technical process at the IMO.

The standard performance of the AIS consists of functionality performance standards, which were set by IMO and IALA; ITU set the technical specifications and IEC adopted the type approval standards.

SOLAS Convention Chapter V/19 requires all ships of 300 gross tonnage and upwards, engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and passenger ships irrespective of size built on or after 1 July 2002 to be fitted with AIS, and for ships engaged on international voyages constructed before 1 July 2002, according to the following timetable:

- Passenger ships, not later than 1 July 2003,
- Tankers, not later than the first survey for safety equipment on or after 1 July 2003,
- Ships, other than passenger ships and tankers, of 50,000 gross tonnage and upwards, not later than 1 July 2004,
- Other than passenger ships and tankers, of 300 gross tonnage and upwards but less than 50,000 gross tonnage, will be required to fit AIS not later than the first safety equipment survey after 1 July 2004 or by 31 December 2004.

ITU recommendation M.1371-1 provides various types of AIS stations:

- Class A: Ship borne mobile device meeting IMO SOLAS carriage requirements,
- Class B: Ship borne mobile device, interoperable with Class A units but not in full accord with IMO SOLAS carriage requirements,
- Search and Rescue Aircraft: aircraft mobile device supporting surface search operations,
- Aids to Navigation – augments visual aids to navigation,
- Base [Shore] Station – Shore-based device supporting VTS and surveillance services.

3.3 The Purpose of the AIS

According to IMO Resolution MSC 74 (69) Annex 3,"The AIS should improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS)" (13). The AIS must satisfy the following functional requirements as specified by IMO recommended performance standards:

- In a ship-to-ship mode for collision avoidance,
- As a means for littoral States to obtain information about a ship and its cargo,
- As a VTS tool, i.e. ship-to-shore (traffic management) (IMO, 1998).

According to IALA Navguide (2001, p.113).“Universal AIS is an emerging ship and shore based broadcast system, operating in the VHF maritime band. Its characteristics and capability will make it an outstanding new tool for enhancing the safety of navigation and efficiency of shipping traffic management”.

The AIS transmits the ship’s data to other ships and shore stations and receives other ships and shore stations data without involvement of ship’s officers. Furthermore it is capable of displaying such data in both text and graphical formats to ships and stations fitted with AIS. The AIS information is broadcast in form of messages.

The AIS also has the capability of identifying vessels, assisting in the tracking of targets, facilitating and simplifying the information exchange and reducing verbal mandatory ship reporting and ship-ship, ship-shore verbal communication.

According the IMO AIS recommended performance standards specified in resolution MSC.74 (69), the AIS must be capable to be functioning in three modes as follows:

- Autonomous and continuous mode for operation in all areas (broadcast mode),
- Assigned mode for operation in an area subject to a competent authority responsible for traffic monitoring such that authority may set the transmission parameters,
- Polling or controlled mode where the data transfer occurs in response to interrogation from a ship or competent authority.

3.4 The Information of AIS

“The received AIS information will mainly support collision avoidances on ships. In VTS stations, the information will be used to monitor traffic” (Berking, 2003, p.62). Four different types of messages can be transmitted by the AIS:

- Static information includes the ships identity and particulars, such as MMSI, name, call sign, IMO number, length and beam, type of ship, location of position fixing antenna and height above keel. The information is updated every 6 minutes or on request.

- Dynamic information includes automatically updated information from the ship's sensors, ship's position with accuracy indication and integrity status, position time stamp in coordinated universal time (UTC), course over ground (COG), speed over ground (SOG), heading, navigational status and rate of turn. The information-updating rate depends upon the frequency of course and speed alterations. Table 3.1 indicates the dynamic information-reporting rate according to IMO recommended performance standards.

Table 3.1 – Report rate of dynamic information

Type of ship	**General reporting interval**
Ship at anchor	3 min
Ship 0-14 Knots	12 sec
Ship 0-14 knots and changing course	4 sec
Ship 14-23 knots	6 sec
Ship 14-23 knots and changing course	2 sec
Ship >23 knots	3 sec
Ship >23 knots and changing course	2 sec

Source: International Maritime Organization. (2002), Guidelines for the onboard operational use of ship borne Automatic Identification System (AIS): (A 22/Res.917). London: Author.

- Voyage related information includes ship's draught, type of hazardous cargoes, if any, destination, ETA, route plan and persons onboard, which is updated every 6 minutes.
- Short safety related information; an assigned free format text message capable of transmitting messages up to 158 characters could be used to

transmit messages containing information related to the safety of navigation. The short safety related messages can be considered as additional means of broadcasting maritime safety information and does not replace the GMDSS obligations and requirements; the information updating is set as required.

The AIS information is broadcast in form of formatted messages at determined intervals. According to IALA guidelines on the universal automatic identification system- operational issues (2002, p.44),"there are some 22 different types of messages included in the AIS Technical Standard, ITU-R M.1371-1 which not only contain the transmitted information but serves various other system or data link functions including message acknowledgement, interrogation, assignments or management commands." Table 3.2 illustrates each message identifier with the description of the message content and the operation mode.

Table 3.2 - Primary Message Types (in groupings) and Operating Modes

Message Identifiers	**Description**	**Operation Mode**
1,2,3	Position Report - scheduled, assigned or response to polling	AU,AS,
4	Base Station Report - position, UTC/date and current slot number	AS
5	Static and Voyage Related Data - Class A SME	AU,AS
6,7,8	Binary Messages - addressed, acknowledge or broadcast	AU,AS,IN
9	Standard SAR Aircraft Position Report	AU,AS
10,11	UTC/Date - enquiry and response	AS,IN
12,13,14	Safety Related Messages - addressed, acknowledge or broadcast	AS,IN,
15	Interrogation - request for specific message type	AU,AS,IN
16	Assignment Mode Command - by competent authority	AS
17	DGNSS Broadcast Binary Message	AS
18,19	Class B SME Position Report - standard and extended reports	AU,AS
20	Data Link Management - reserve slots for Base Stations	AS
21	Aids to Navigation Report - position and status report	AU,AS,IN
22	Channel management	AS

Source: IALA. (2002), IALA guidelines on the universal Automatic Identification System (AIS) : Volume 1, Part I – Operational Issues Edition 1. St Germain en Laye: Author.

(AU: Autonomous - AS: Assigned - IN: polling / interrogation)

A new target symbols was adopted by the IMO on interim basis to differentiate between the presentation of AIS information and existing ARPA and ECDIS presentation, when the AIS is graphically displayed. IMO interim guidelines for the presentation and display of AIS target information set the specifications of graphical presentation and display of AIS information as standalone system or when integrated with another navigational aid or system.

The AIS target symbols, which were recommended by the IALA, define five types of AIS target symbols:

- Sleeping target: it indicates the presence and orientation of a vessel equipped with AIS in a certain location;
- Activated target: it represents the activation of a sleeping target automatically or manually, for the display of additional graphically presented information;
- Selected target: it represents the manual selection of any AIS target for the display of detailed information in a separate data display area. In this area, received target data as well as the calculated closest time of approach (CPA) and time to closest time of approach (TCPA) values will be shown;
- Dangerous target: it represents an AIS target (activated or not) which data exceeds pre-set CPA or TCPA limits;
- Lost target: it represents the last valid position of an AIS target before the reception of its data was lost.

Correlation between primary radar targets and AIS targets is likely to be required to reduce the risk of overloading the radar screen by data from different sources i.e. ARPA and AIS. IALA recommends a cost effective way to display the AIS information on personal computer (PC) radar like display, which allows the measurement of the target's bearing and distance in order to compare with the radar for identification.

3.5 The Operation Principles of AIS

Each AIS station consists of a VHF transmitter, two VHF SOTDMA receivers, VHF DSC receivers for channel management, global navigation satellite system (GNSS) receiver providing time for the timing of slot synchronization, and marine electronic communications link to shipboard displays and sensor system, in order to satisfy the recommended performance standards of IMO.

Probably the only GNSS is mostly used at the moment is GPS; perhaps in the future the Galileo satellites, the GNSS under development by the European Commission (EC) and the European space agency (ESA), will be in use when in service.

Two VHF channels were designated by the ITU for the operation of the AIS, namely AIS1 channel 87B – 161.975 KHZ and AIS2 channel 88B – 162.025 KHZ, allowing the AIS to detect and identify targets at the VHF operating ranges of about 30 to 40NM.

The AIS is capable of switching automatically to regional alternate designated channel if both the designated channels are fully occupied. The system being GMDSS compatible, allows shore based GMDSS system to establish AIS operating frequency and to identify and track AIS equipped ships.

3.5.1 The SOTDMA Technology

AIS is an autonomous and continuous broadcast system, operating in the VHF maritime mobile band. With the capability of handling numerous reports at fast update rates, the SOTDMA technology allows the system to meet with these high broadcasting rates, ensuring reliable and efficient operation.

AIS station provides 4500 time slots per minute of the same length. Two VHF channels of 2250 time slot per minute each equally divide the 4500 time slots. The 2250 time slots constitute a frame and each frame is repeated every minute as shown in figure 3.1.

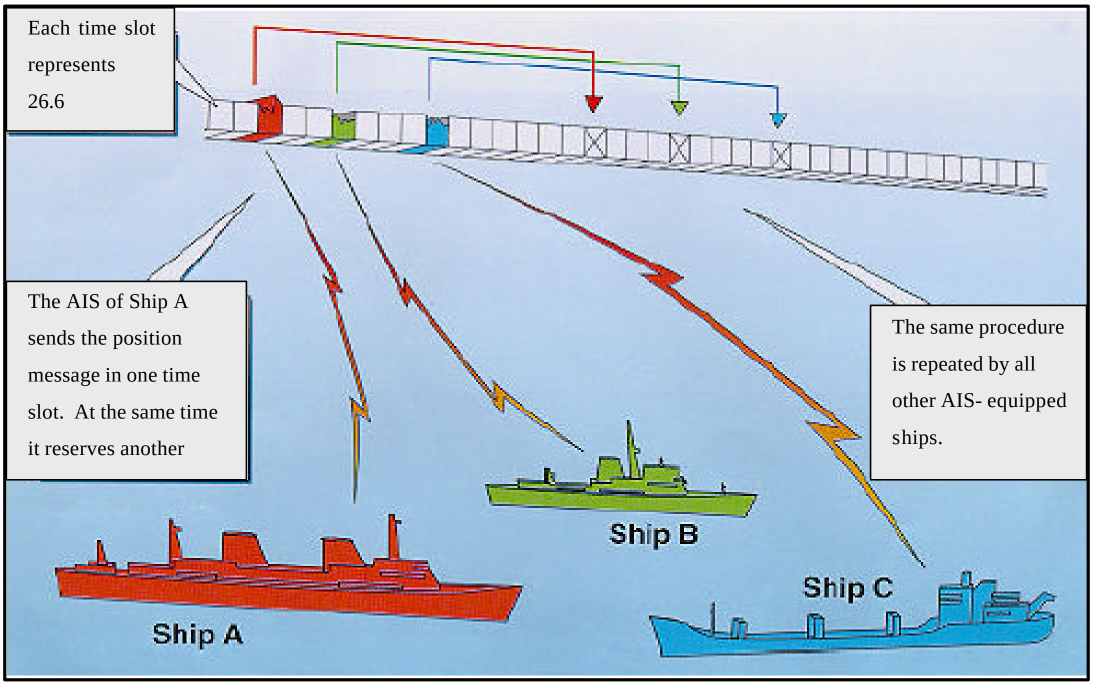

Figure 3.1 - Principles of SOTDMA
Source: IALA. (2001), IALA Aids to Navigation Guide (Navguide). St Germain en Laye: Author.

A position report message occupies one time slot; other reports may occupy more time slots. By using the UTC time information, the time slots are accurately synchronized. The system is also capable of using a secondary independent time mechanism with 10µs accuracy.

The SOTDMA allows each AIS station to determine its own transmission schedule using the time slots and continuously synchronizes the different AIS stations to avoid the overlapping of the transmission of time slots among them. Moreover, it ensures the continuous receiving of new stations, including those stations that suddenly come in the VHF range of the receiving station.

In circumstances when the system is overloaded with many messages received from many AIS stations, the SOTDMA produces gradual reduction of the radio cell size, by dropped out transmissions from AIS stations far away (more than 8-10NM), thus giving priority to those closer to the receiving station.

According to IMO recommended performance standards (1998), the system must have a minimum reporting capacity of 2000 reports per minute considering the coverage range of 40NM. An estimate of 3000 reports per minute was calculated for the Singapore straits and 2500 for Dover strait (IALA-Navguide, 2001). The minimum reporting capacity should be increased, at least for the shore based stations, to enable them to cope with the vast number of ships transits in certain areas of the world.

3.5.2 Data Input in AIS Stations

One of the AIS main principles is to allow exchange of shipboard information automatically from the ship's sensors to other ships and shore station. As figures 3.2 shows, the shipboard component of AIS consists of three elements: a communications medium, an assembly that takes the various inputs and organizes them into AIS message format, and a display that presents incoming data to the user (Transportation Research Board, 2003).

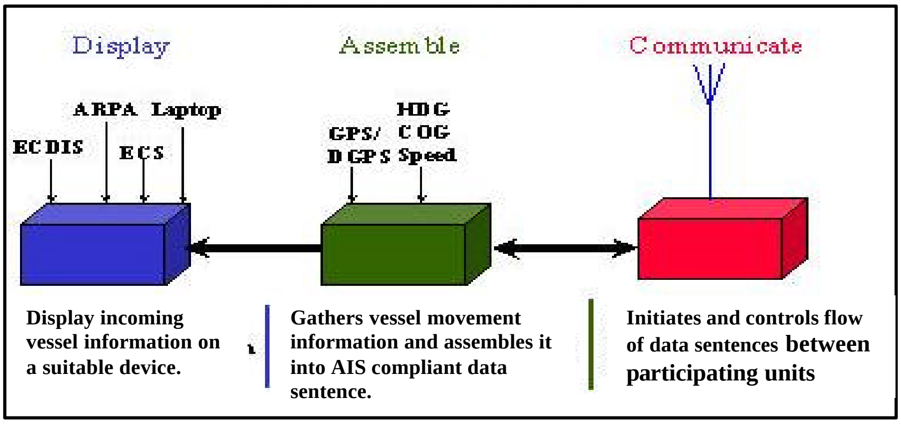

Figure 3.2 – Elements of AIS

Source: Transportation Research Board (2003). Shipboard Automatic Identification System displays: meeting the needs of mariners. Washington, D.C.: National Academy of Sciences.

The AIS ship originated data under the pre-mentioned type of information will be as follows:

- Static information is set on installation and stored in the system and needs to be changed only if major changes take place,
- Dynamic information, (as illustrated in Table 3.3)
- Voyage-related information is manually entered to the system at the start of the voyage or whenever changed,
- Short safety related information is manually entered to the system when required.

Table 3.3 - Details of the AIS dynamic information

Dynamic information	**Data input**
Ship position with accuracy indication and integrity	Automatic update from position sensor* with accuracy indication of about 10 meters
Position time stamp	Automatically updated from main position sensor or secondary mechanism
Course over ground	Automatically updated from main position sensor
Speed over ground	Automatically updated from main position or speed sensor**
Heading	Automatically updated from main position or heading sensor***
Navigational status	Manually entered by the operator
Rate of turn	Automatically updated from ship's ROT sensor or derived from Gyro compass

Source: International Maritime Organization. (2002), Guidelines for the onboard operational use of ship borne Automatic Identification System (AIS): (A 22/Res.917). London: Author.

Note: Provisions are made for input from external sensors of additional information
* GNSS (GPS, DGPS)
** GNSS or Doppler log
** GNSS or Digital Gyro compass if available

3.5.3 The Reliability of AIS Information

The reliability of the information provided by the AIS is a critical issue and was considered in approving the system in "IEC standard 61993". It sets the type approval test specification and the error checking mechanism of the shipboard AIS, which includes test specification, data in and out standard, connector standard and built-in integrity test (BIIT) details.

The BIIT is running continuously or at appropriate intervals monitoring the availability of data and error detection mechanism of the transmitted data. In case of any AIS malfunction, an alarm is provided and the unit should stop transmitting, as well as error checking of the received data. For example, if no sensor is installed or if one of the sensors fails to provide data, the AIS automatically transmits the "not available" data value.

3.5.4 Displaying and Presentation of AIS Information

The minimum information which is displayed by shipboard originated AIS messages is the Position, COG, SOG, Heading and rate of turn (ROT) or direction of turn as available as specified in the IMO SN/Circ.217. Additional aspects should be considered when the message is shore originated, bearing in mind that the requirements for display depend upon the type and volume of data provided from the shore.

Shore-originated AIS messages may include information about aids to navigation, pseudo aids to navigation, meteorological or hydrological data, the identity, position, and dimensions of offshore structures, VTS waypoints or route plans, shore-based radar target information from a vessel traffic center and the radar images which were converted and retransmitted to AIS-equipped vessels.

In harmonizing shore-originated AIS messages, IALA (2001) is considering a three-tiered structure that would provide international applications controlled by IMO, regional applications controlled by regional organizations and local applications controlled by national authorities or local organizations.

IMO resolution A.917 (22) specifies only one type of display known as minimum keyboard and display (MKD), which incorporates a three-line display screen of 16 alphanumeric. It presents bearing, range and name of a selected ship. Other data can be obtained by scrolling.

The data may also be displayed integrated with ECDIS, radar or stand-alone graphic display. Displaying the information on ECDIS or radar screen provides generic overview of the traffic situation and early identification of potential critical situations.

Probably the main reasons behind limiting the performance standard of AIS to minimum of MKD are the question of the availability of the modern radars or ECDIS on board all ships. ECDIS is not a mandatory equipment to be carried yet on board ships and many old types of radar in operation at the moment are unable to be upgraded. Perhaps in the future ECDIS and modern Radar/ARPA will be the only tools to display the AIS information.

IMO is in a process of setting requirements for the display and use of AIS information on ship borne navigational displays to replace the present interim guidelines specified in IMO SN/circ. 217, by establishing a working group to work on draft performance standards for the presentation of AIS navigation-related information, including the harmonization of terms and symbols.

The proposed draft was submitted to IMO NAV 50th session on the 23rd of March 2004, which takes into consideration, the adoption of a consistent human machine interface philosophy and implementation, as well as the priority over presentation requirements of the individual performance standards for relevant navigational systems and equipment, in case of conflicts.

3.6 Comparison Between AIS and Radar

The purpose and functionality, which was discussed in brief earlier in this chapter, raise some questions such as whether the AIS replaces the radar, and whether the AIS technology is the new innovation of technology, which will replace the radar technology. In answering those questions the performance of both systems needs to be compared.

3.6.1 Detection of Targets

The basic principle of marine radar is the transmission of radio wave pulses in a horizontal beam by a directional antenna. When the waves hit an object, some of the reflected energy is reflected back to the antenna. The distance is obtained by knowing the time difference between transmitting and receiving, while the bearing is obtained from the direction of the antenna at the time of reception.

The number and type of objects detected by radar are unlimited and not restricted to certain conditions. The radar detects coastline, aids to navigations, ships and other objects, while the AIS operations are limited to ships or objects fitted with AIS.

Radar can detect objects only within the line of sight of its antenna, and it has a shadow area, so it cannot detect targets around bends or behind higher objects. However the AIS can detect any target fitted with the system within its area of coverage.

The AIS when activated can detect and identify objects fitted with it, in addition to structures, an accessible network of information available to all the ships and stations fitted with the equipment, while the radar operation is limited to detection of targets for the purpose of navigation, collision avoidance and management of traffic.

3.6.2 Coverage and Accuracy

The radar coverage depends on many factors, such as the height of antenna, height of object, the type of object, e.g. wooden object, steel or concrete object, low land or high mountains, as well as the layout of the area of coverage and others.

Weather, sea conditions or the presence of any precipitation such as rain and sea waves reduce the radar coverage, limit its accuracy and obscure the display of the targets. Furthermore, the radar has difficulty in the discrimination of targets when at close bearings or ranges in certain specific conditions.

> According to Berking (2004, p.2),
> The radar has to cope with many performance compromises, which add to the restrictions of the radar capabilities, e.g.
>
> - Larger coverage versus better discrimination,
> - Improved clutter reduction versus risk of target suppression,
> - True motion overview versus relative motion risk management,
> - Head-up presentation versus north-up presentation,
> - Ground stabilization versus sea stabilization,
> - Integration of chart information versus information overload,
> - High functionality versus high operational load.

The AIS signal is carried on VHF frequency; furthermore, the AIS operation principle is different from the radar and does not depend on the reflection properties of the reflected signal. Therefore, the effect of weather and sea conditions on the AIS signal is barley noticeable compared with the radar; moreover, the AIS has no difficulty in the discrimination of targets.

3.6.3 Tracking of Ships

The information provided by the AIS, such as COG, SOG and the heading of a tracked ship is derived directly and updated from the sensors of the ship being tracked. This will result in the delivery of accurate information at high update rate, providing that the sensors and the ship's equipment are functioning properly.

AIS provides real time navigation silently, since the information exchange between the involved targets will take place electronically, which will also facilitate the traffic monitoring by shore surveillance station and VTS.

It is not the same case with radar or ARPA, which calculate the COG, SOG between two or more successive scans of the antenna. This will result in significant delay before they provide the information. If a ship is altering course, it is not before some time that the radar or ARPA will indicate that.

Moreover, masking of radar observation, due to the presence of buildings or other obstructions, may cause the radar to lose tracking of a number of targets. As a result of produced shadow area in certain sectors of the VTS area.

Conclusions

The Radar does not need any support from the target to detect; moreover, the target can not hide from the radar, if it is in range and the line of sight of the antenna, "non co-operative tracking", while the AIS can only operate with targets which are fitted with the system, "co-operative tracking".

In a scenario where all ships are fitted with only AIS, and suddenly a ship runs out of main and auxiliary power in the middle of Singapore or Dover Strait, what would happen? The result will be a blind ghost ship that cannot see anybody and nobody can see her and the consequences could be catastrophic.

The AIS is a value added to the radar and does not replace it. The integration of the radar and AIS will improve the quality and reliability of information with regard to target detection and tracking and will overcome some of the radar shortcomings, including target swap and target loss due to clutter or fast maneuver. Both the radar and AIS will compensate each other for their individual limitations and deficiencies when integrated together.

Chapter 4

AIS and the Role of the Information Technology in VTS Operations

Descriptions of VTS and AIS operational principles were discussed earlier in chapters 2 and 3. This chapter will discuss the impact of applying the AIS information technology on the VTS operations.

The type of AIS used in VTS systems is a shore-based device supporting VTS and surveillance services, as specified by ITU recommendation M.1371-1. The AIS base station could perform several functions including:

- Acting as the main link between the mobile AIS stations (onboard ships) and the VTS,
- Acting as repeater to rebroadcast the AIS information,
- Managing the radio channels, including the use of alternate channels when AIS1 and AIS2 are busy,
- Interrogating AIS mobile stations, when authorized to do so.

In order to determine what the AIS may add or change in the VTS operations, in other words how the VTS will benefit from the information provided by AIS, the areas of the VTS operations have to be identified and discussed. These operations, which will be affected and influenced by applying such technology, as well as the integration of this new technology with existing tools and equipment, used in VTS systems.

Applying the AIS technology will improve many of the VTS functions, if not all of them. The following will identify how the information technology may contribute in improving VTS operations, by clarifying the effect of such technology on each VTS function related to the safety, management and monitoring of maritime traffic.

4.1 Identification and Communication

While the use of radar in VTS was limited to the detection and tracking of ships, the identification and communication, with the traffic passing through VTS areas, was mostly done verbally using the VHF.

Different methods have been used to identify ships, such as setting mandatory reporting system. Ship reporting schemes are approved by IMO and follow specific reporting formats as laid down in IMO Resolution A.851 (20). Ships in VTS area should adhere to the mandatory reporting system, by identifying their identity and their geographical location; by reporting their position coordinates (Latitude, Longitude) or in relative to fixed object (light house, buoy). Mostly all methods of identifying and communicating with the traffic were VHF based.

Failure to comply with the reporting system did happen in many situations. It was not uncommon to receive no response from some ships, as well as, situations of communicating to the wrong ship occurred.

Nevertheless, certain areas experienced difficulties in communication for many other reasons, such as heavy traffic, misuse of VHF equipment, signal distortion, frequency interference and others. Moreover, the verbal reporting is a time consuming process.

Such difficulties affected the reliability of the VHF verbal communication in many situations, and resulted in creating confusion to the VTS and ship's officers; thus endangering the safety of navigation.

The AIS is providing a great facility in identifying ships by supplying the information of the ships, including ship's name, call sign and MMSI number, as the ship's name may not be unique in some cases. Knowing the MMSI and call sign of a ship confirms its identity. Using a database management system in a VTS may possibly be another way to confirm a ship's identity.

The ship's identity is contained in the AIS position report, which is transmitted to other ships and shore stations. Being part of the static information, it is updated every 6 minutes or on request by the competent authority, in the polling mode according to IMO recommended performance standards for AIS, as specified in resolution MSC.74 (69).

AIS provides rapid identification of the passing ships and the ability to communicate with them in the VTS area, which is considered to be one of the cornerstones in establishing a comprehensive traffic image. AIS provides such service automatically without the interference of the ship's officers, or depending on their compliance to the mandatory reporting system; moreover, the AIS does this function silently.

The maritime and port authority of Singapore evaluated the performance of the AIS system in a pilot project in 1999, and the results indicated that AIS ship transponders could reduce a VTS operator’s time spent on verbal communications by as much as half (Sollosi, 2002).

The use of AIS technology will eliminate the need for voice communication or at least reduce it, which will also facilitate the use of VHF effectively in emergency situations, for non AIS carrying ships and when verbal confirmation is required in certain situations. Moreover, it will overcome the weaknesses of the current manual reporting process.

4.2 Safety of Navigation

The information provided by the AIS to VTS operator, the rapid exchange of information between the VTS and traffic and the automatic update of the information will improve the situational awareness, and as a result will have a positive impact on many aspects, which contributes to the safety and quality of navigation.

4.2.1 Navigational information

In addition to broadcasting static, dynamic and voyage related information of the transiting ships, the safety related messages, which are also broadcast by the AIS, will provide a tool to VTS and ship's officers to exchange additional information as it occurs, and this will improve the situational awareness of all parties.

The short safety related messages (up to 158 characters) are one type of messages, which are transmitted and received by ship and shore stations. As it is set in free text format, it can be used to broadcast or address different types of information, mainly related to the safety of navigation, such as maritime safety information (MSI), navigational warning and storm warnings.

The binary messages are defined as the automatic exchange of information. It is another type of AIS messages and it is also called AIS telegrams. Binary messages are standard messages, structured in predefined information packages.

Each message is dedicated to a different application and can be broadcast to all stations or addressed to a specific MMSI. Navigational application includes:

- Notice to mariners,
- Pilot services,
- Meteorological services,
- VTS navigational advise e.g. speed limits,
- Tidal information.

According to IMO NAV\49\18,

> Binary addressed and broadcast messages contain a binary data field and an application identifier. This application identifier identifies how the binary data field has to be interpreted. The application identifier consists of:
>
> - Designated Area Code (DAC),
> - Function Identifier (FI).
>
> The designated area code defines the following different branches of application identifiers available:
>
> - International Application Identifier (IAI) branch for global use,
> - Various Regional Application Identifier (RAI) branches, the use of which will be defined by the competent regional body.
>
> Every Function Identifier (FI) within the (IAI) branch is associated with a definition of an International Function Messages (IFM). (3)

The IMO is in a process of harmonizing, selecting and administering the important applications/functions of the binary messages, to avoid the use of the same FI for different applications in different parts of the world, to control the increase of IAI and RAI globally and for the international recognition of the different identifiers.

4.2.2 Aids to Navigation

Aids to navigation such as buoys, light vessels and lighthouses are of different types, shapes and characteristics. They are used for the purpose of navigation assistance among other usages, particularly in near coastal waters, narrow waters, prohibited areas for navigation and other critical navigational areas.

VTS centers use aids to navigation for different purposes, such as marking traffic separations, port approaches and marking or organizing the traffic near a danger to navigation.

A special type of AIS station, introduced by ITU Recommendations M.1371-1, the (AtoN AIS station) when fitted to an Aid to Navigation could provide information including:

- Identification of the aid to navigation,
- State of health of the navigational aid,
- Tide and weather conditions,
- Act as an AIS base station repeater.

Furthermore, it can monitor the performance of the navigational aid, as well as, the collection of AIS data of the transiting maritime traffic for navigational planning purposes, which will facilitate the management and monitoring of traffic by VTS, as well as, improving the ability to monitor the performance of aids to navigation remotely.

Additional potential benefit of the AIS is the transmitting of the so called "Pseudo/virtual aids to navigation" for physically non existing objects, which can be used for many purposes such as, marking a prohibited area for navigation or naval exercise area.

4.2.3 Broadcasting of DGNSS and ECDIS Corrections

GNSS were introduced and used by navigators. The GPS is the most accurate and globally used system. The Differential GPS (DGPS) is a regular GPS with an additional correction (differential) signal added. This correction signal improves the accuracy of the GPS to about 5 meters or less, with 95% probability.

Broadcasting DGPS corrections using the AIS by the VTS center will enable all ships equipped with AIS and GPS receivers in the VTS area to navigate with DGPS accuracy, which improves the position fixing accuracy; hence, it will improve the safety of navigation.

Additionally, the VTS can use the AIS in broadcasting electronic chart corrections for the VTS area and local waterways, for ships equipped with electronic charts, which will enhance the chart information validity onboard the transiting ships.

4.2.4 Radar Targets Broadcasting

The VTS can attach the information of a non-AIS vessel to its radar target and broadcast it as Pseudo AIS target message to other vessels equipped with AIS in the VTS area.

Moreover, this function will allow non radar equipped vessels, which are only equipped with AIS, to view the VTS radar targets, which will increase their situational awareness of all the surrounding traffic, and will enhance the level of safety of navigation in the VTS area.

HITT, leading manufacturer of vessel traffic and port management systems, had set up an AIS test bed in the port of Rotterdam, providing the VTS foot prints (position and speed of non AIS targets) to the piloted vessels. According to (Hogendoorn, 2004, p.420), "this kind of service is technically feasible, despite the high traffic density within the port."

4.2.5 Metrological and Hydrological Information

The metrological information, such as weather conditions and hydrological information, such as current and tide conditions are the most vital information required by the navigators, in order to proceed safely in their voyages. Receiving accurate information at the right time can save the ship, the crew and the environment.

One of the services provided by VTS centers is the information service, which includes weather information among other types of information as specified by IMO resolution A.857 (20). The AIS can play a crucial role in broadcasting the metrological and hydrological information, and such broadcasting will depend on the type and capability of the measuring and processing equipment.

The metrological and hydrological information may be broadcast in separate messages, according to the operational requirement. The message may include:

- Wind speed and direction,
- Water level and temperature,
- Wave height,
- Air temperature,
- Current speed and direction on different depths,
- Tide information.

The benefits of broadcasting such information using the AIS are the delivery of the information to the ship's officers in real time.

4.3 Management and Monitoring of Maritime Traffic

The appropriateness of the judgments, decisions, interventions, evaluations and conclusions made by the VTS operator mainly depend on the credibility, reliability and accuracy of the compiled traffic image, in order to respond to the traffic situations.

Adding the AIS as a sensor or additional source to gather the required information to create the traffic image will improve the efficiency of navigation and the management of the maritime traffic in the following fields.

4.3.1 Detection, Tracking and Monitoring of Targets

Tracking of targets throughout the VTS area is the most crucial operation, following the detection and identification of them. The dynamic information provided by AIS in real time will improve the tracking process. The accuracy of target position being GPS based, particularly after May 2000, when the USA discontinued the use of selective availability, added value to the accuracy of AIS information.

For the first time the VTS operator will be able to determine whether the ship is moving ahead or astern, the exact rate of turn of the ship, the navigational status, keeping in mind it is manually entered by the ship's officers. This will provide the VTS operator with additional vital information such as when the ship is at anchor, moored, aground and not under command, which will improve the reliability of the VTS traffic image.

Ships draught, destination, hazardous cargo type (if any), ETA and other voyage related information, which are manually fed by the ship's officers, will contribute positively in the monitoring process. For instance VTS operator can decide route plans for the transiting ships or pilot boarding position for a specific ship based on such information.

By broadcasting the route plan using the AIS to the VTS, a vessel can report its sailing plan (intended route) using the AIS to the VTS for verification and approval. The VTS may approve it or propose another route plan (Hogendoorn, 2004).

The information provided by the AIS will facilitate, for the VTS operator, the evaluation of the developing situations in VTS area, including the interaction between individual ships been tracked. Furthermore, it will assist in determining the obligation to give way according to convention on the International Regulations for Preventing Collisions at Sea (COLREG), which will improve and add value to the VTS navigational assistance, when required.

Long range automatic reporting and tracking could contribute significantly to the improvement of maritime safety, traffic management and flow in the congested ports and waterways, using the AIS automatic data transfer, long range tracking could function by VTS, which can satisfy different objectives for many States.

USA proposed the long range tracking to IMO in the MSC 78th session to enhance maritime security, whereas in Europe it was tested in the BAFEGIS project to enhance the safety of the ro/ro ships and ferries, by monitoring them from berth to berth between Sweden and Germany in the Baltic Sea. Numerous applications of the long-range tracking can be utilized.

Long-range tracking could be done using the VHF frequencies and a number of repeater stations; furthermore, it could be used to monitor ships at longer range when interfaced with the INMARSAT satellite receivers or any long-range communications system.

Ferries were tracked between Bilbao/Spain and Southampton/UK in the European project “POSEIDON” using the INMARSAT-C position reports (Harre, 1999).

4.3.2 Integration of AIS with VTS equipment

In order to play its role in the surveillance of maritime traffic, VTS systems are provided with hardware, which includes the surveillance equipment, and software systems.

Hardware includes radars, ARPA, ECDIS, AIS, radio communication systems, video cameras, radars track processor and recording, weather sensors and others. Software includes flexible graphical user interface, flexible map management system, and interface for data exchange. Both hardware and software contribute in creating the VTS traffic image.

The integration of navigational equipment onboard ships and in VTS centers has been increasing significantly in recent years. Perhaps in the near future standalone equipment will not be available in the market, but only as spare parts for the integrated systems

When the radar and AIS sensors detect the same target in VTS systems, and since the operational principles of both systems are different, each system will show a different symbol and may detect the target at different positions. Therefore the resulting conflict of information may confuse the operator.

In order to overcome this problem, VTS systems are provided with software filters, which can integrate both symbols according to preset criteria and display it as one target. This is called target fusion or multi/sensor fusion, indicating to the operator which sensor is used for the target data calculations.

ECDIS is another important sensor in VTS, providing it is International Hydrographic Organization (IHO) S57 edition 3 formatted and approved by the national hydrographic authority. Integrating ECDIS with radar/ARPA (the so called radar chart) and AIS will allow the VTS operator to monitor the chart, targets and target information in one screen.

According to (Andrianov, 2003, p.11), " ECDIS allows target identification not only by AIS… three layers of target on display. There are targets from ARPA connected to ECDIS, from the digital radar board (radar integrator) which process targets from the scanner, and from the AIS."

ECDIS displays the geographical features, waterways and navigational lanes as background picture on the VTS screen; it also displays the ships' echoes in the same screen, which is larger in size and conspicuous when compared with the radar or MKD.

When AIS is integrated with ECDIS and radar/ARPA, it will improve the ability of the VTS operator to observe the geographical and hydrographical features of the VTS area and the traffic situation simultaneously; furthermore, each system will compensate the other's deficiencies.

Such integration would strengthen the ability of the VTS in providing navigational advice, based on a comprehensive picture. Moreover, the utilization of the ECDIS monitoring alarm systems are an added benefit to traffic monitoring, such as off track deviation and safety contour alarms. For instance if a deep draught vessel is approaching shallow water patch, the ECDIS will warn the VTS operator.

Modification to the software used in the VTS systems must be implemented, to interface the AIS sensor with the other existing sensors; such modifications shall include the ability of the software to (Harre, 2002):

- The interpretation of AIS messages,
- The indication of which sensor is use in tacking the targets,
- Implementing of a target fusion criteria to set the weight given to the AIS,
- The ability to adjust AIS data, which is manually entered, to match with accessible database stored data of the target, including the data acquired by radio communication,
- The ability to broadcast, address and receive the AIS messages,
- The ability to detect irregularities in the reception of AIS messages (missing message detection), including track prediction over particular time period,
- The integration of AIS into VTS recording.

Hecht, Berking, Buttgenbach, Jonas and Alexander (2002) argue that the consistency is needed for the new generations of radar technology that combines radar/ARPA /ECDIS and AIS for the display and certain activation function like the automatic acquisition. In this context, the following principles have been proposed to the IMO:

- All AIS targets are displayed by symbol independent of the existence of radar echoes or ARPA targets,
- The display of radar echoes should remain visible under the AIS symbol,
- For all activated targets, automatic ARPA tracking of the corresponding radar targets should be initiated as long as these targets are not yet tracked,
- The guard zone for ARPA should be used as a guard zone for AIS targets,
- The vector time applied to all AIS target vectors is the same as the ARPA vector time,
- Cancellation of an AIS target cancels both AIS activation and ARPA tracking.

The integration of VTS sensors will provide redundancy in detecting, tracking and displaying systems, which will facilitate the detection and tracking of targets. Consequently this will ensure the safety and efficiency of navigation, as well as the management and monitoring of maritime traffic.

4.3.3 Shipping and Port Management

Accommodating the AIS as an additional sensor to the VTS systems, will contribute in improving the quality of shipping information services, which will support the trend of converting VTS to VTMIS by providing wider comprehensive traffic information.

According to IALA guidelines on AIS as a VTS tool (2002, p.9), "Increasing emphasis is being placed on networking VTS centres on a regional basis … the rapid transfer of vessel details between different centres. Adoption of AIS within the relevant VTS centres may contribute toward this process."

AIS information technology will integrate shore and ship in one information network. The VTS will be the central point in the network acting like the main bridge, linking the ship with all other parties involved in maritime operations. World Wide Web (internet) or similar technology may contribute to form the required communication link.

Information from ship to VTS will be the first step, followed by information exchange from VTS to another VTS within the same region forming a regional network. Furthermore, information exchange between VTS networks will lead to the establishment of an international shipping information network.

The benefits of exchanging information, such as ETA, destination, carried cargo, hazardous cargo onboard, draught and other voyage related information would serve and facilitate many of the economic performance purposes.

Furthermore, it will ensure the efficiency of maritime transport as part of the integrated transport system. Utilizing such information for planning purposes will assist in maximizing the utilization of the available resources.

In Austria transponders are being installed and tested in order to use them as components of the control system for ships dispatching. By this, the waiting time at the locks will be reduced by giving speed recommendations to Masters, which will allow entering the open locks without previous mooring maneuvers with waiting time (Hossfeld, 2003).

The information network will facilitate and improve shipping management and logistics chains, in applying the modern logistics approach of “just in time” by providing reliable, valid and accurate information in real time to all parties involved such as shipping companies, pilot organizations, port authorities, maritime administrations, consignees, shipping agents, stevedoring companies, immigration departments, customs and terminals.

What will the situation be when a ship arrives at a port, assuming that all ships and VTS centers are equipped with AIS? As the ship approaches the VTS area, where the port of destination is located, the VTS and ship will commence to exchange information, and through the information network, all other stakeholders will have access to the same information.

The pilot station will be notified and will organize for pilot boarding. The port authority, terminal and stevedores will prepare for the berthing and cargo operations, including cargo transshipment arrangement. The agent will prepare the required paper work and clearances for the ship, and the consignee will be notified in order for the cargo delivery arrangement.

Information demand and type of information required, which varies from region to region around the globe, will drive the network design. Nevertheless, all operations will be done automatically without a spoken word or any time wasted in communications; it will be part of the VTS automatic internal communications.

4.3.4 Maritime Security

In the current international heightened security situation, following the attacks on the USA in September 2001, and the adoptions of new comprehensive maritime security measures by IMO in international diplomatic conference on maritime security in December 2002, the VTS role in ensuring the national security has grown in many countries, adding to the responsibilities of the VTS.

Handling security related information within the VTS information network, resulted in adding the security organizations such as coastguard organizations to the client's list of VTS.

AIS information could be of security advantage to the authorities in monitoring and the traffic approaching or passing through its coastal waters. Furthermore, under the authorization of the authorities, the polling or controlled mode, as specified in AIS performance standards, will allow the VTS to interrogate specific data from ships at any time within the AIS coverage.

Adopting the long range tracking using the AIS, being discussed in IMO Sub-Committee on Radio communications and Search and Rescue (COMSAR), will improve the efficiency of monitoring the traffic for security purposes by extending the AIS range beyond VHF, using long range communications technology, e.g. INMARSAT, which will facilitate the interrogation of ships in the Exclusive Economic Zone.

Exchanging security related information within VTS networks on regional and international bases will strengthen controlling and combating piracy, hijacking of ships and other crimes or terrorist acts against ships on an international basis.

4.3.5 Remote Pilotage

The AIS would contribute positively to shore-based pilotage, using the navigational information provided by the AIS in real time. A pilot located in the VTS center could guide a number of ships simultaneously, using his local knowledge of the area and the information technology provided by AIS.

The accurate navigational information provided by the AIS will make the shore based pilotage feasible, for many factors include:

- The accessibility to the ship's navigational data, derived form its sensors, to the pilot in real time, will allow him to take the necessary action in ample time,
- The ability to discriminate precisely on presenting displays the target of the piloted vessel among other targets in the area,

- The positive identification of the ship throughout the whole pilotage process,
- The rapid communication facility provided by AIS will overcome the drawbacks of using the VHF.

Another type of remote pilotage could be practiced, using remote portable pilot units (PPU). PPU could consist of a PC provided with electronic chart software and AIS. PPU can provide the master or pilot with a comprehensive traffic image and it can be used in situations including:

- Exempt Masters of the regular calling ships of carrying pilot in certain ports or waterways,
- Pilots can use it onboard ships not fitted with ECDIS, and non-SOLAS ships or other ships not fitted with modern equipped bridge.

Experiments were carried out in Tokyo Bay in 2002, using the PPU in a project intended to support the safe navigation and berthing maneuver in port areas in Japan. (One of a series of Marine Intelligent Transport System projects in Japan). In this experiment, the port traffic management system (PTMS) server receives a planned route of all ships using AIS, and check for dangerous encounter situations. The server transmits a warning signal using AIS if any dangerous encounter situation was detected, (Hagiwara, 2004). Further experiments were carried out in Australia and the Netherlands.

4.3.6 Search and Rescue

SAR centers being one of the VTS allied services will benefit from the AIS technology. Rescue Coordinating Centers (RCC) could benefit from the VTS traffic image, which contain all the information of the vessels in the VTS area ready in hand.

The information obtained by AIS, VTS information databases and the other functionality of AIS, will facilitate and improve the efficiency of SAR operations, when SAR units are fitted with AIS transponders. This includes the following:

- Gathering information about the distressed vessel and monitoring its position,
- Gathering information of the other vessels in the vicinity, which will enable the RCC to determine which vessel, will be able to assist, including which could serve as on-scene commander,
- Tracking of the SAR units including aircraft, for the best use of the RCC resources and the safety of the SAR units and crew,
- In carrying out the search patterns, to ensure the entire coverage of the search area, as well as reducing the time spent on SAR mission, which will have the RCC available for other SAR missions when they arise.

4.3.7 Other VTS services

In addition to the benefits associated with the use of AIS, as a VTS tool in the main functions of VTS, implementing the AIS technology will improve many other VTS operations, related to the safety, management and monitoring of maritime traffic.

Furthermore, the VTS allied services can benefit from the AIS information technology in many operations including:

- Improving the efficiency of protecting the environment and the control of pollution caused by ships, by continuous monitoring and tracing of traffic,
- The networking of the offshore operation including the movement of offshore supply vessels and helicopters. It could be used to ensure the safety of navigation among other uses, particularly for oilfields located in crowded areas e.g. Gulf of Mexico and Gulf of Suez,
- Recording of the AIS information could be used for maritime causality investigations, port state control operations and other maritime administration matters,

- Developing shipping and traffic statistics, as a result of the recording and archiving of the information, which could assist in decision-making and planning in many of the maritime fields including, traffic route planning and international trade,
- Control of fishing and other economic resources activities,
- Fleet management, by monitoring and tracking certain fleet.

The AIS is a recently added tool to the VTS. The further use and familiarity of it, in the management and monitoring of traffic will certainly provide additional operational insights, which may contribute positively to reduce the workload for the VTS operator. Furthermore, it will eliminate or solve some of the limitations associated with its use, which will be discussed in the next chapter.

Chapter 5

Limitations Associated with the Use of AIS in VTS Operations

In order to utilize the AIS technology in the VTS operations, VTS operators, ship's officers as well as other parties' involved in monitoring, management and safety of maritime traffic must be aware of the system limitations and downsides.

Probably the most vital issue the VTS operators have to take into account is that not every vessel is required by the rules to carry AIS. Therefore the AIS will not be capable of providing the full picture of the maritime traffic in the VTS area unless it is integrated with other surveillance systems.

On the other hand it is equally important that ship's officers transiting the VTS area should be able to identify whether the VTS station is equipped with AIS or not. Perhaps such information should be available in the admiralty list of radio signals (ALRS), world VTS guide and other related publications and sources.

Moreover, the full comprehensive overview of the surrounding waterways and traffic, which AIS provide, may encourage a number of ship's officers to breach the COLREG. This could endanger the other vessels in the VTS area, especially the smaller non-AIS equipped vessels, which may not appear on radar display, adding to the workload of the VTS operators.

The AIS system was initially designed to serve collision avoidance, in addition to the VTS in the monitoring and management of traffic and maritime security matters.

Hurriedly, VTS organizations, as well as other organizations involved, intended to use the system in many additional applications.

The questions raise themselves now:

- Is the system, with the present specifications is able to achieve its initial intended functions, as well as, other additional applications, safely and efficiently?
- What are the implications on the maritime security, with regard to the availability and accessibility of the AIS information?
- Are the personnel in charge of operating the system, onboard and ashore, trained and familiar with its capabilities and limitations?

In answering these questions, the system limitations have to be defined. Defining such limitations will improve and facilitate the utilization of the system, for the benefit of the safety of navigation. Moreover, it will assist organizations involved in the design, as well as technical and legislative sides in overcoming such limitations in the future.

5.1 Validity of Information

The validity of AIS information is one of the basic foundations of compiling comprehensive traffic images for the VTS, in order to ensure safety of navigation, management and monitoring of traffic; furthermore, it is the keystone in building a shipping information network.

Voyage related information is one type of information, which is manually entered by the ship's officers. Failure to correctly enter or update this information into the system will result in establishing unreliable traffic images and information network.

The BIIT checks only the integrity and functionality of AIS; therefore, the validity and accuracy of the navigation related information (dynamic information), which is generally derived from the ship's sensors, would mainly depend on the performance of the sensors of the transmitting ship.

Various ships' sensors are fitted with individual integrity checks but not all of them; hence; the duty of checking the validity of the broadcasted information lies on the ship's officers, who are subject to human errors and fatigue.

According to IMO resolution A.917 (22) "If the master believes that the continual operation of AIS might compromise the safety or security of his/her ship, the AIS may be switched off." (3). Switching off the AIS will affect the reliability of the AIS as one of the VTS sensors and source of information. Moreover, it will fade the validity of the information provided by the VTS to other concerned parties.

For instance, if the system is used by the VTS to provide information to other VTS allied services and clients e.g. agents, RCC and pilot stations, switching off the system will stop the flow of information leaving the VTS with non-valid information, although it is necessary for safety and security considerations.

In addition to the above limitations, certain significant information is not included in AIS information packages, which is important to the VTS operations in managing and monitoring of the traffic such as, Harre (2002) states:

- Ship's nationality (Flag),
- Ship's gross tonnage,
- Air draught,
- Ship's agent,
- Sailing condition (transiting ship or port calling),
- AIS dynamic information must be provided with data age, particularly the information that is used in tracking the traffic.

5.2 Security and Confidentiality of Information

Information Service and navigational assistance are the most vital services provided by VTS. They assist Masters on taking the right navigational decisions. Both types of services and others are provided through the exchange of information between the ship and VTS. Additionally, the VTS is required to share and communicate information with many other organizations, in order to facilitate maritime traffic, shipping and port management.

Breaching of information has become easy, as a result of the vast improvement in communication technology; consequently, AIS broadcast information may contribute negatively to the ship security as well as commercial confidentiality.

Piracy, terrorism and other organized crimes against ships are planned depending mainly on pre-collected information about the ship. The accessibility of AIS broadcast information may assist in the collection of information by illegal organizations, which could be used to attack or threaten ships.

In the AIS environment, everybody can see everybody, in other words, critical and comprehensive data of the ship are exposed to the public. For instance, type of cargo, crew nationality, route plan and destination, so such information could be valuable for evil intent organizations.

Additionally, false information could be transmitted using the AIS, to misguide the authorities and other ships, in order to attack or carry out other illegal acts against ships or States, so VTS systems may require to establish secured and accurate database to authenticate vessels using the AIS.

Furthermore, the implementation of the long-range identification and tracking of ships is a necessity, in order to effectively utilize the AIS technology in the national maritime security. The 30 to 40 NM coverage range of VHF may be enough for an evil intent ship to attack or breach the security of a State.

5.3 Overloading the System

The vast increase in the installation of AIS onboard ships and VTS stations, as a response to local or international regulations, as well as using it in other applications, including the intent to create shipping information networks using the AIS information technology as a communication link, will contribute to the overloading and congestion the AIS network, providing that all these functions are done using the two AIS assigned two VHF channels.

The dispersal of information on the AIS screen, particularly in busy water such as, several VTS areas may overload the work on both the VTS operator and ship's officers, increasing the possibility of making mistakes.

Bearing in mind, that the AIS base station is in charge of allocating the time slots for the repetition and transmission of message from and to the AIS mobile station, it is essential that the AIS base station ensure that the transmitted messages does not reduce the available time slots for the vessel to vessel collusion avoidance function.

On the other hand, the 4500 time slots per minute provided by the AIS station may not be sufficient to handle the huge amount of information been broadcast. Consequently, the SOTDMA may reduce the radio cell extremely by dropping out transmissions from AIS stations, which may reduce the coverage and functionality of the system. However, the position report has the priority in broadcasting, leaving limited bandwidth available for other information, particularly for shore to ship information.

"H.Ericsson, the sales manager of SAAB Celsius transponder technology, emphasizes that AIS should not be regarded as just a convenient way of pushing data around. The AIS link is not intended to carry bulk data, because shipping should always have first claim on any available time slots" (Safety at Sea International, 2004, 38, 424).

5.4 Displaying and presentation of information

An organizational structure of shore originated information messages including, specification, update rate, presentation, alarms, indications and symbols have to be established. The standardization of shore-originated information will provide a common operating environment, which will ensure the safety of navigation.

The AIS target symbols, as specified in IMO SN/Circ.217, the interim guidelines for the presentation and display of AIS target information, as well as, the proposed draft performance standards for the presentation of AIS navigation-related information may not be suitable for VTS.

The VTS centers require a wider range of information than it is necessary on board ships; however, when it is required to transmit the position of a vessel from the VTS center using the AIS, it will be necessary to be transmitted in terms, which will be recognized by the vessel (IALA, 2002).

Although the IMO is in a process of developing new measures for adopting mandatory performance standards for the onboard AIS, the new proposed standards leaves the question of minimum display requirements unspecified, leaving the MKD, as the minimum required displaying equipment.

MKD may considered to be useless, if both the VTS operator and the ship's officer fail to identify which target on the radar display relate to which information report on MKD. The situation may become more complicated for the targets out of the radar range. Moreover, the effort to identify such relationship by the operators may decrease their surveillance abilities, endangering the safety of navigation.

The track fusion function serves to avoid the presentation of two target symbols for the same physical target, which may overload the radar screen and cause confusion for both VTS operator as well as ship's officer. According to IMO NAV 50/4 "… as a default condition, the activated AIS target symbol and the alphanumeric AIS target data should be automatically selected and displayed." (8)

Taking into consideration the different operational principles of both the radar and AIS, particularly the different update rates used by both systems in collecting ship's data and monitoring ship's maneuver, there is so far no defined standards or specifications regarding setting track fusion criteria in VTS stations. Such criteria include:

- The weight of data obtained from each system,
- The principles used in integrating data obtained from the radar and AIS,
- Presetting the filter characteristics,
- Priority of presentation requirements over the individual performance standards of each system.

Currently, various VTS manufacturers set different criteria; hence this will reduce the reliability of the shore-originated information and may create confusion or misjudgment, particularly for the pseudo targets, which are retransmitted to the traffic by the VTS.

Perhaps, certain requirements should have been settled and regulated before setting the mandatory regulations to carry AIS onboard ships and recommending it as VTS tool. Already most SOLAS ships and a considerable number of non-SOLAS ships are equipped with AIS, yet the IMO is still in the process of developing standards for presentations and displaying of AIS broadcast information.

Nevertheless the IMO working group involved in the presentation of AIS navigational information recommends that the performance standards of ECDIS need to be reviewed to introduce new requirements in order to serve as AIS navigational information display.

5.5 Coverage and Accuracy

Presently the only reliable GNSS is the GPS, which is one of the AIS station components, which provide time for the timing of slot synchronization as well as position redundancy; therefore, the AIS operation is mainly dependent on the accuracy and functionality of GPS.

Being dependent on only one positioning system is a disadvantage to AIS accuracy as well as reliability, keeping in mind that GPS in a national military system, particularly if the ministry of defence in the US decided to re-apply the selective availability in the context of the heightened security measures, which was implemented following the attacks on USA in September 2001.

Major GPS breakdown on one satellite occurred on January 1, 2004 in Jobourg VTS in France. The surveillance team who logged all vessel VHF reports during this breakdown, observed the following: some GPS receivers were not able to provide a position for approximately one hour; some receivers transmitted position reports with very large errors of about 1 nm (Marechal, 2004). Perhaps in the near future when the Galileo satellite system is operational and reliable, this will provide redundancy to the GNSS and eliminate such weakness.

In the principle of operation of AIS, the SOTDMA is organizing the time slots for all AIS stations within VHF range. However, assuming that two ships approaching the VTS area at the same range but from opposite directions, both the ships may use the same time slot, as they are out of range from each other. Consequently, this may create confusion and will demolish the accuracy and reliability of data.

AIS is the perfect solution to many of the VTS problems. Assuming that mobile AIS stations in the VTS area broadcasting correct data, keeping in mind that AIS is a "co-operative tracking" system, and the accuracy of AIS information, particularly the navigational related information, are depending entirely on the accuracy of the data fed by the sensors of transmitting station, such mutual dependency may create threats to the safety of navigation.

However, if the data being transmitted by mobile AIS stations in the VTS area is in conflict with the data obtained from the radar, such conflict may confuse the VTS operator as well as ship's officer transiting the VTS area.

Furthermore, while AIS tracking overcomes most of the radar track shortcomings such as masking and target swap, according to IALA VTS manual (2002, p.51), "…buildings and bridges can cause difficulties for AIS transponders in heavily built-up areas. This is a consequence of inhibiting either the reception of the differential GNSS signal by the AIS transponder, or the transmission of the subsequent AIS message."

5.6 Additional AIS Applications in the VTS area

Although the carriage requirement for AIS has been introduced following a relatively small number of small-scale trials, many maritime authorities are encouraged to proceed in applying this technology in additional fundamental maritime applications, before it is properly tested or approved feasible for such operations including:

- **Remote pilotage**: It is doubtful that remote pilotage can replace the physical presence of pilot onboard the ship in many situations. The physical presence of the pilot on the bridge is very important for many reasons, such as his local knowledge and experience of the area including the meteorological and hydrographical conditions, physical observance of the ship's manoeuvre, the overstress on the bridge team, as well as the ability to communicate with tugs and mooring gangs.

AIS is a piece of equipment liable to failures and breakdowns like any other equipment. However, the consequences of an AIS breakdown situation while a ship is being remotely piloted in a critical or narrow waterway may differ, if the pilot is present on board physically.

- **Aids to Navigation:** the pseudo buoy and other floating navigational aids will encourage the ship's officers to rely totally on the AIS and ignore lookout of the bridge windows. Albeit visual sighting is an important method in observing and assessing navigational aids, as well as, the motion of other ships and other surrounding features.

  Perhaps before employing the AIS in such application, the AIS device has to be tested for the exposure as well as the extreme motion, which buoys and other aids to navigations are usually exposed to.

  On the other hand, focusing only on the bridge electronic screens by the ship's officers may endanger the safety of navigation in the VTS area in certain situations, such as equipment failure and extreme metrological conditions.

5.7 Training and familiarization

Definitely, among the fundamentals of ensuring the safety of navigation in VTS areas are the familiarization with the existing systems and the level of knowledge, competence and skills of VTS operator as well as ship's officers, particularly in dealing with traffic situations. Competencies, such as the ability of using the available navigational tools and VTS sensors efficiently and understand their potentials and limitations are essential.

Yet, there are no training standards on the AIS operation either for ship's officer or VTS operator, despite the fact that the system is already operational and mandatory.

IMO has to consider setting mandatory rules for the training of the use of AIS equally to ARPA and radar in the STCW Code, and prepare a model course for the operation of AIS onboard ships similar to IMO Model Course 1.27 “ the operational use of ECDIS”. Similarly IALA has to begin amending its present VTS training model courses to include the training in the use of AIS for VTS Operators.

Although the performance standards and the standard of displaying and presentation of AIS information have not been finalized yet by IMO and other concerned organizations. Nevertheless, training standards and curriculum for model courses in the AIS operation onboard ships and VTS centers can be developed based on the present IMO, IALA, ITU and IEC guidelines, technical specifications and recommendations.

Such technical publications contain definitive information available to the maritime education and training (MET) institutions, administrations and other training providers. However the training and model courses can be readdressed and amended once the experience of using the AIS technology is gained.

At the present time some work is in progress by some concerned parties. Positively it may end up with the implementation of training standards for AIS. For instance the fifth VTS training workshop was held in February 2003 in Rotterdam with the objective to identify the impact of AIS on VTS operators, including possible training requirements, among other objectives.

Furthermore, IMO STW sessions 34 and 35 discussed the submitted documents by the UK and International Federation of Shipmasters’ Associations (IFSMA), regarding the training requirements for the use of AIS onboard ships.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

VTS were established to ensure the safety and efficiency of navigation and the protection of the environment. VTS basically provide four types of services in order to achieve its objectives, namely information services, navigational assistance, traffic organization services and co-operation with allied services and adjacent VTS.

The crucial factors, which VTS operations are based on, are the ability to compile a comprehensive traffic image of the VTS area. The technology used in providing the traffic image may vary from an old style analogue radar display to the use of modern sophisticated ECDIS associated with radar and AIS information.

More factors are involved in the VTS performance, including the level of proficiency the VTS personnel have, and their ability to respond to traffic situations, as well as performing other VTS tasks. Moreover, there are methods and operations the VTS implement, including the setting of operational rules and regulations.

In order to utilize the VTS facilities in additional tasks, the scope of utilization of VTS was broadened to include commercial and maritime security activities. This resulted in the adoption of the VTMIS concept.

A new system was introduced to the maritime industry by the IMO in the SOLAS convention. The AIS uses the SOTDMA technique, which was invented initially for the aviation industry, allowing stations to broadcast identification and information reports at regular and short intervals. IMO had recognized the importance of AIS information in VTS operations.

The study has defined and discussed the benefits of applying AIS information technology in VTS operations. AIS will assist VTS in achieving its objectives, in managing and monitoring the maritime traffic safely and efficiently and protecting the environment, as well as serve as a great tool in economical and security related operations. Moreover, it will assist many VTS allied services in performing their operations.

The study has revealed that AIS can provide information as a standalone system in textual format form, using the MKD. Integrating AIS with other display systems, such as ECDIS, ARPA and radar will provide a generic view of the traffic situation. Compiling comprehensive traffic image will assist VTS operators in the early identification of critical situations.

Despite the fact that AIS has overcome many of the radar shortcomings, this study illustrates that AIS cannot replace the radar, which detects targets without the need of their assistance. Certainly AIS is an added value to radar. Both systems when integrated together will improve the quality and reliability of information. Moreover they will assist VTS in compiling more reliable and accurate traffic image, particularly in the field of detection and identification of targets.

On the other hand, SOLAS ships and a significant number of non-SOLAS ships are equipped with AIS, yet the performance standards of AIS, including the standards for presentations and displaying of AIS broadcast information, have not been settled and regulated. Perhaps AIS required more research and development as well as trial periods before it was set mandatory to be carried onboard ships.

Finally, the author believes that AIS is seen as a solution to many of the VTS problems; however, there are many issues to be resolved. A number of AIS limitations, when associated in VTS operations have to be settled. Furthermore, the intention of introducing AIS technology in many other fundamental maritime applications, such as remote pilotage, SAR operations and shipping management, with the existing limited broadcasting capacity, will overload the system and reduce its validity, reliability and credibility.

6.2 Recommendations

Based on the analysis and study in the preceding chapters, the author suggests a number of recommendations. These recommendations could be put forward to VTS Competent Authorities, law-making bodies such as IMO, other organizations concerned with performance and functionality of VTS and AIS, such as IALA, IEC and ITU. In terms of their nature, the proposed recommendations are classified as follows:

- **Performance**

Measures should be taken to set mandatory performance standards for both ship borne AIS (class A) and AIS base station. Special attention should be given to the performance standards of the displaying and the presentation of the AIS information on other navigational equipment, such as ARPA, radar and ECDIS.

Furthermore, a criteria for track fusion should be established, when AIS is integrated with other navigational equipment. Moreover, the shore-originated information should be standardized to ensure a common operating environment.

Additionally, more technical work is required to improve the functionality of the BIIT check, including establishing a comprehensive integrity test, which can test the validity of the ship's sensors data.

- **Coverage**

Measures should be taken to: either adopt a parallel system for data communications for the general messages, leaving AIS for navigation related functions, or broaden the existing AIS broadcasting bandwidth in order to accommodate the growing number of ships and shore stations utilizing the AIS.

- **Security**

In order to distribute AIS information in safe and secured way, information server functionality standards for the AIS network has to be established. Such standards should include an authentication system for more sensitive information, as well as stringent accessibility procedures to the server's information. For instance, users can only access the information related to their area of operations. Moreover, users of the network must be identified and registered with the VTS authorities.

More technical work is required to implement the long range tracking in order to utilize the system efficiently in maritime security matters.

- **Training**

AIS training requirements have to be defined for both VTS operators and ship's officers. For ship's officers, it should be embodied in the standard of competence for the defined shipboard functions, as specified in the STCW Code. Furthermore, guidance and recommendations should be provided to MET institutions in order to implement the training programmes.

Similarly, the existing standard of training and qualification of VTS operators should be modified to include AIS training requirements.

6.3 Further Research

- The level of knowledge and skills, ship's officers as well as VTS operators require, with regard to the operation of AIS, is one of the fundamentals of ensuring the safety of navigation in the VTS area. The required skills and knowledge have to be specified. Furthermore, methods of assessing skills and knowledge have to be established.

  A training programme have to be established based on a preset training standards, different training schemes could be implemented including, on the job training, class room training and simulator training.

- The feasibility of using AIS in additional maritime application requires more research work. Maritime applications including, remote pilotage, SAR operations, shipping management and others could be enhanced using the AIS.

  In performing such research, certain consideration must be kept in mind including, the impact of introducing AIS technology on those applications as well as, the impacts on the AIS network, and the possible overload on the AIS network.

- The impact of introducing AIS on the planning, implementation and operational issues of VTS have to be examined. How the operational, technical and administrative infrastructure of the VTS will be affected or may require to be modified to accommodate AIS among other VTS sensors.

- The need to establish performance standard for AIS base station, bearing in mind that, type and size of information handled by VTS are different from that handled onboard ships.

- The possibility of increasing the limited bandwidth, which AIS uses for broadcasting information, or adopt a parallel system for handling non-navigational related information, leaving AIS for navigational related information.

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